CFIRE

Estimating the Effects of Extreme Weather on Transportation Infrastructure

CFIRE RI-05
December 2016

National Center for Freight & Infrastructure Research & Education
Department of Civil and Environmental Engineering
College of Engineering
University of Wisconsin–Madison

Authors:

Janey V. Camp and Mark D. Abkowitz
Vanderbilt University

Principal Investigator:

Janey V. Camp
Vanderbilt University

This page intentionally left blank.

Technical Report Documentation

1. Report No. CFIRE RI-05	2. Government Accession No.	3. Recipient's Catalog No. **CFDA 20.701**
4. Title and Subtitle Estimating the Effects of Extreme Weather on Transportation Infrastructure		5. Report Date **December 2016** 6. Performing Organization Code
7. Author/s Janey V. Camp		8. Performing Organization Report No. **CFIRE RI-05**
9. Performing Organization Name and Address Vanderbilt University 400 24th Avenue, South Nashville, TN 37235 United States		10. Work Unit No. (TRAIS) 11. Contract or Grant No. T002688
12. Sponsoring Organization Name and Address Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE Washington, DC 20590 United States		13. Type of Report and Period Covered **Final Report 9/1/2012–12/31/2016** 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Climate change, already taking place, is expected to become more pronounced in the future. Current damage assessment models for extreme weather events, such as FEMA's Hazus, do not take the full impact to transportation systems into consideration. As a result, the consequences of climate change scenarios on freight transportation infrastructure and the system network, including disruption to commodity freight flow and access, are not well characterized. This research develops and pilots test a methodology that estimates the actual transportation infrastructure cost of a climate change-induced event, with an initial focus on flooding of highway infrastructure in the Nashville, TN, region for which impact data is readily available. Additionally, at a larger scale, geographic information systems can be utilized coupled with downscaled climate model projections to perform screening-level analysis of transportation infrastructure assets that may be most at risk. Performing a screening-level analysis can assist decision makers in knowing where to allocate resources for additional analysis using the approach developed for Nashville, TN. This is demonstrated using NARCCAP model output as the source for identifying "regional" or localized "hot spots" for evaluation using Hazus or other tools for the eastern portion of the United States. Ultimately, the two approaches presented can be used individually or combined to provide evaluation at multiple levels of decision support using publicly available tools to estimate the potential risk under future climate conditions to transportation assets.

17. Key Words Floods; Infrastructure; Risk analysis; Transportation modes; Weather conditions; Extreme events	18. Distribution Statement **No restrictions. This report is available through the Transportation Research Information Services of the National Transportation Library.**		
19. Security Classification (of this report) **Unclassified**	20. Security Classification (of this page) **Unclassified**	21. No. of Pages 19	22. Price **-0-**

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized.

Estimating the Effects of Extreme Weather on Transportation Infrastructure

Janey V. Camp[1] and Mark D. Abkowitz[2]

Abstract

Climate change, already taking place, is expected to become more pronounced in the future. Current damage assessment models for extreme weather events, such as FEMA's Hazus, do not take the full impact to transportation systems into consideration. As a result, the consequences of climate change scenarios on freight transportation infrastructure and the system network, including disruption to commodity freight flow and access, are not well characterized. This research develops and pilots test a methodology that estimates the actual transportation infrastructure cost of a climate change-induced event, with an initial focus on flooding of highway infrastructure in the Nashville, TN, region for which impact data is readily available. Additionally, at a larger scale, geographic information systems can be utilized coupled with downscaled climate model projections to perform screening-level analysis of transportation infrastructure assets that may be most at risk. Performing a screening-level analysis can assist decision makers in knowing where to allocate resources for additional analysis using the approach developed for Nashville, TN. This is demonstrated using NARCCAP model output as the source for identifying "regional" or localized "hot spots" for evaluation using Hazus or other tools for the eastern portion of the United States. Ultimately, the two approaches presented can be used individually or combined to provide evaluation at multiple levels of decision support using publicly available tools to estimate the potential risk under future climate conditions to transportation assets.

Introduction

Given the anticipated changes in climate for the future, it is important to understand the impacts of anticipated climate change scenarios on the transportation infrastructure, both its availability and use. Existing damage estimation models generally concentrate on economic impacts, and often omit corresponding environmental and social impacts and some infrastructure types such as transportation. As a result, the impact of climate change, especially changes in the intensity and frequency of precipitation, is often omitted from transportation infrastructure planning. In particular, disruption to commodity freight flow and access over the next few decades is not well characterized.

The objective of this research is to develop and pilot test a methodology that would estimate the actual transportation infrastructure costs of flooding and related climate change impacts. This information will fulfill an important, as-of-yet unmet need for the transportation community in identifying infrastructure that is most threatened, as well as in determining the full benefits of candidate adaptation strategies.

---

[1] Research Assistant Professor, Department of Civil and Environmental Engineering, Vanderbilt University, Nashville, TN. janey.camp@vanderbilt.edu

[2] Professor, Department of Civil and Environmental Engineering, Vanderbilt University, Nashville, TN. mark.d.abkowitz@vanderbilt.edu

The specific research objectives were identified as the following:

- Develop and pilot test a methodology that can identify *highway* infrastructure that is most threatened by *flooding* events.
- Define the correlation between flooding and road closures as an initial component of a transportation and extreme weather risk index.
- Estimate the actual damage due to flooding to the highway infrastructure itself and related indirect effects (e.g., delays in shipments, increased travel times and fuel costs).
- Provide a means for: 1) evaluating the potential impacts of extreme weather on highway infrastructure systems due to flooding and 2) determining the benefits of candidate adaptation strategies.
- Provide a basis for transferability of the research results to:
    - Flood risk associated with other freight modes
    - Risks of other extreme weather events impacting freight transportation infrastructure and operations

To accomplish these goals, the research was divided into two primary areas (1) examine the ability of publicly available tools and data to identify "at risk" infrastructure components" and predict potential damages under extreme flooding conditions at a local level and (2) provide a basis for using regional downscaled climate models to perform screening-level analysis to identify and prioritize localized transportation system components for which the aforementioned, local-level analysis can be utilized to assess potential risks.

Approach

Part 1 – Examine the Ability of Publicly Available Tools such as FEMA's Hazus to Estimate Potential Risks and Damages to Transportation Infrastructure Assets at a Localized Scale

Case Study – Nashville, TN 2010 Flooding Event

In May of 2010, the middle Tennessee area was crippled by an extreme precipitation event that resulted in over 13" of rainfall in less than a 48-hour period. The flooding resembled 500-yr or 1000-yr event flood levels depending on the tributary or receiving waterbody in question. There were 11 fatalities and an estimated $2 billion in damages to private party as a result of the event. Thousands of claims were filed with FEMA for assistance. Many of those affected (~46%) were located outside the 100-year flood plain and did not have flood insurance. Economic centers were shut down and freight movement through the region essentially came to a halt. Figure 1 shows the roadways impacted and condition levels in relation to levels of precipitation measured from USGS rain gages. Figure 2 provides a closer look at impacts to roadways as repair costs obtained from the Nashville Metropolitan Government Public Works department in the aftermath of the May 2010 flood event.

Many roadways and rail lines were several damaged or destroyed (at least in part). Equipment fleet and cargo was lost for many shippers and carriers. Waterway navigation was halted for several days as one lock was completely submerged in the area. Repairs to infrastructure took months for some assets forcing customers to find and use alternative routes and modes for shipments.

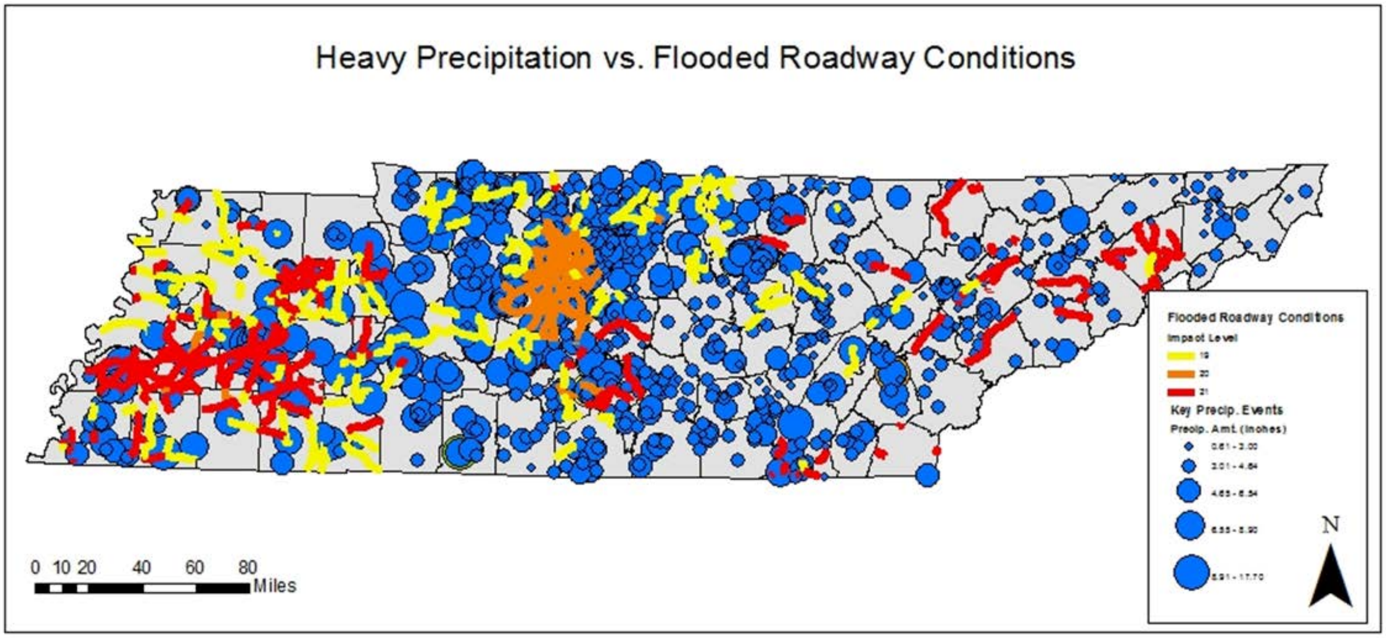


Figure 1: May 2010 Flood Event Roadway Issues in comparison to observed heavy precipitation locations

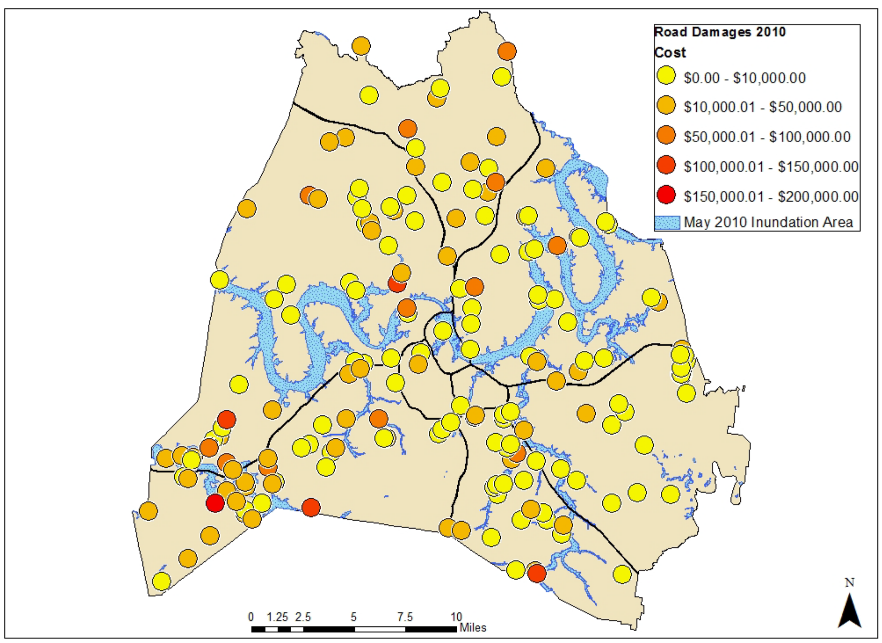


Figure 2: Nashville area roadway damages from local government repair information superimposed on flood inundation area for the May 2010 event

Using the Hazus Flood Model to Estimate Damages

Hazus-MH for floods was developed by FEMA for use as a mitigation planning tool where communities and others could approximate the potential damage costs to properties based upon census data and commonly used depth-damage functions from the US Army Corps of Engineers (USACE) and others. Hazus for flooding performs two-dimensional (2D) estimation of the flood extent and depth for a multicounty or smaller region using elevations from a digital elevation model (DEM). The U.S. Census Bureau's census data including housing, some demographics, and economic factors is used for approximating damage costs, number of individuals to be relocated, debris generated, impacts to essential facilities, etc. The user can either perform Level 1 Analysis (only the built in "fill the bathtub" flood modeling approach) or can perform Level 2 analysis using HEC-RAS or other more advanced flood model outputs to approximate damages. Figure 3 presents a sample of Hazus output on the number of buildings requiring complete or partial replacement per census block in the Nashville area using a USACE HEC-RAS model calibrated to the May 2010 flood levels.

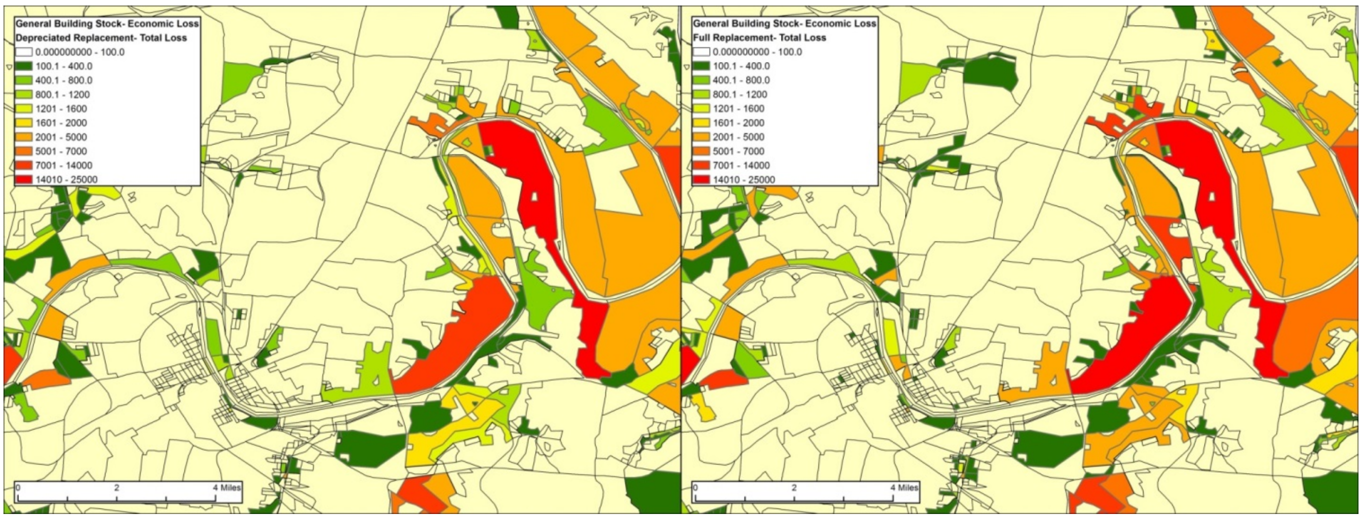


Figure 3: Estimated number of buildings requiring partial or complete replacement per census block for USACE HEC-RAS model calibrated to 2010 Nashville flood depths. Left map – number of buildings requiring partial replacement; Right map – number of buildings requiring complete replacement.

Hazus modeling was performed using both Level 1 "out of the box" analysis for a 1000-yr flood event and Level 2 analysis with USACE HEC-RAS model output calibrated to the 2010 flood event in Nashville to evaluate impacts on the community and transportation infrastructure assets. Of specific interest was the extent to which Hazus provided useful and "close" approximations on the actual damages observed in the Nashville area for that event under the assumption that the May 2010 flood event could serve as an example "extreme" event that may be similar to those possible in the future. To the extent possible, data on the true damages and associated costs were obtained from local government offices (e.g., see the roadway repair costs from Metro Nashville's Public Works Department in Figure 2) for comparison with Hazus outputs.

Hazus also provides approximations for indirect damages in terms of displaced persons, business closures, etc. In an effort to quantify the indirect damages experienced by Nashville residents as a result of the 2010 flood, a household survey was performed. Census blocks across the Nashville area were targeted for survey distribution with a range of exposure (Hazus damage levels) and income levels based upon census data. In this, we identified 9 areas to target representing the combinations for income and damage levels (see Table 1) with an additional area (zone 10) evaluated due to knowledge of high impacts to that area (figure 3). The survey instrument is provided in Appendix A.

Table 1: Variables considered in targeting census blocks for the household survey

Low Income	Moderate Income	High Income
Low Damage	Low Damage	Low Damage
Moderate Damage	Moderate Damage	Moderate Damage
High Damage	High Damage	High Damage

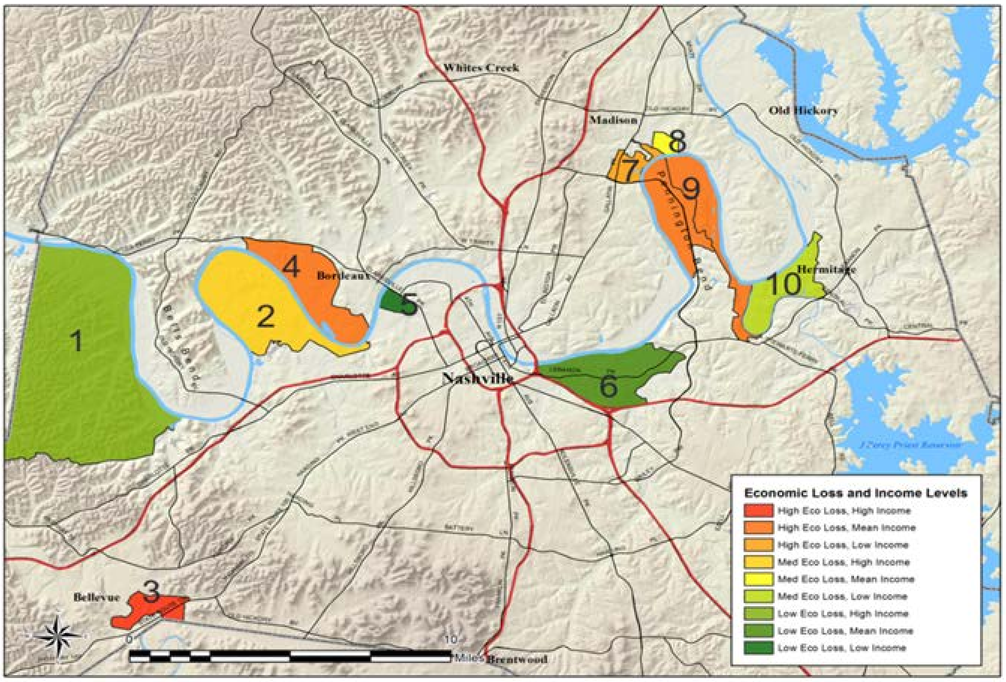


Figure 4: Targeted zones for the household survey

The information gained from local government officials and the household survey was compared to Hazus model outputs to identify the degree to which Hazus can be utilized by local planners to estimate impacts of extreme events (such as those that may be experienced under future climate projections) at a localized level to both transportation infrastructure systems and communities in general.

Part 2 – Regional-level Screening for Transportation Infrastructure at Risk for Future Flooding

Much information exists and with it comes much uncertainty associated with the global projections, suites of models and downscaled model outputs related to climate change. A challenge for practitioners is to know what data to use and account for the uncertainties that exist, which are compounded when global models are downscaled to regional and even smaller resolutions necessary to make informed decisions at the local level. For the purposes of this project, we relied upon downscaled climate data from the North American Regional Climate Change Assessment Program (NARCCAP), which is a public repository of a suite of regional and global climate model combinations (six planned RCMs, each coupled with two of four planned GCMs[3]). A threshold of 2” of average daily precipitation was used to identify “hot spots” in frequency of occurrence for future heavy precipitation across all model pairs for the eastern United States as a proof of concept approach for the years 2041-2070. Two inches was used due to the low number of model outputs instances that exceeded that value with the understanding that in today’s engineering design methodologies, much higher values appear in the 24-hour rainfall frequency curves (or IDF curves) for 50- to 100-yr storm events.   Figure 4 provides a glimpse at the NARCCAP model outputs for area-averaged frequency of precipitation during the warm season for 2041-2017.

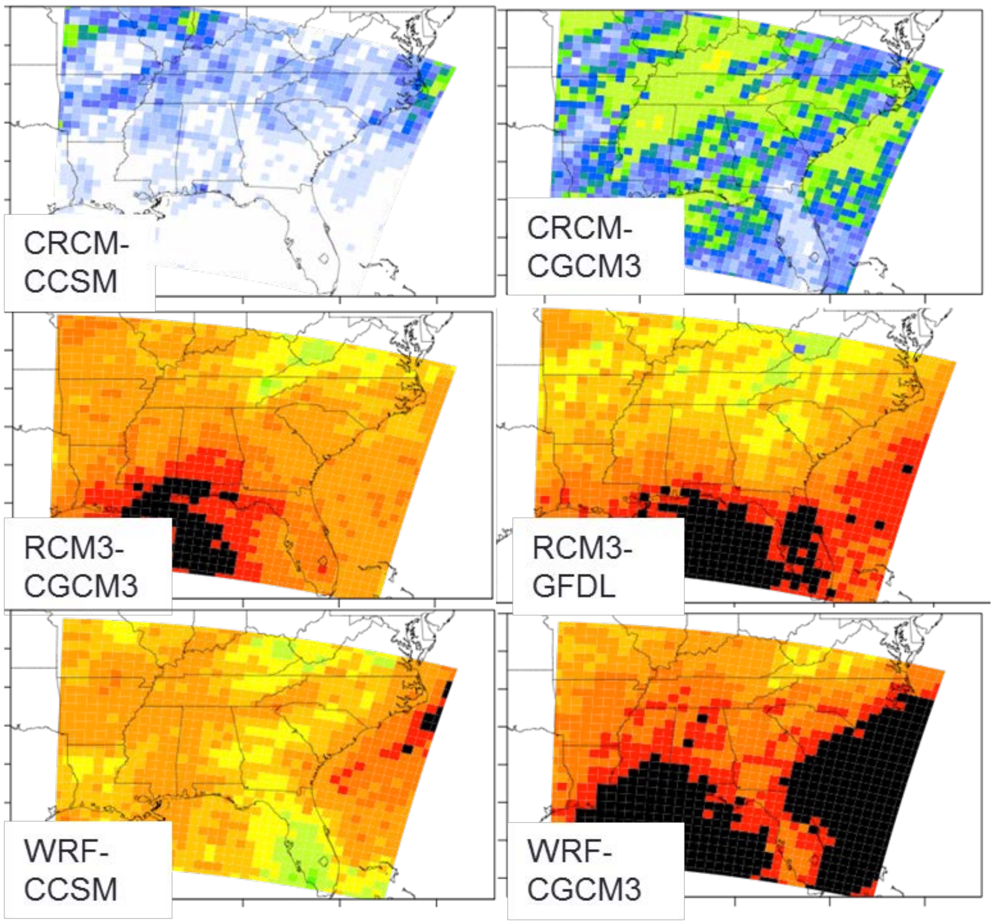


Figure 5: NARCCAP model pairs showing area-averaged frequency of precipitation greater than 2" in the warm season for 2041-2070.

The “hot spots” for future heavy precipitation can be coupled with analysis on key freight corridors both considering current and future freight volumes to identify “at risk” transportation infrastructure components. The Freight Analysis Framework (FAF) was used to represent the highway freight infrastructure system for consideration. A threshold of 10,000 for 2007 truck traffic flows (FAF07) was used to identify critical or key segments of the freight network for this study.

[3] NARCCAP Program Plan. http://www.narccap.ucar.edu/about/plan.html#rcm-gcm

Using ArcGIS Desktop, areas where "hot spots" for frequency of heavy precipitation (daily averages exceeding 2") were mapped as netCDF outputs from NARCCAP downscaled data. Then, FAF07 highway segments exceeding truck traffic volumes of 10,000 were superimposed on the NARCCAP data output for each of the 6 RCM-GBM model pairs for each model year range of 2041-2055 and 2056-2070. The 30-year model outputs were broken into smaller 15-year segments to evaluate whether more severities appeared in the precipitation data as time progressed and a more granular look into whether a "hot spot" early in the mid-century climate approximations would continue to be a "hot spot" in the latter years.

Results

Part 1 – Evaluation of Hazus to Approximate the Damages Experienced in an Extreme Flood Event

Data obtained from Metropolitan Nashville government offices included roadway damage repairs following the May 2010 flood event as well as high water marks on buildings from visible inspection, properties slated for buyout and the list of FEMA assistance applications for reimbursement on behalf of the local government agencies. Additionally data on assistance from various community non-profits and foundations were obtained where possible.

The Metro Planning Office estimated about $2 billion in direct property damages. Hazus estimates the building loss/damages a bit higher using both HEC-RAS model output and the Level 1 analysis with total estimated damages to the area at $9 billion (see Table 2). The only transportation infrastructure considered in Hazus is bridges. Therefore, the damage costs for transportation are likely severely underestimated. In an attempt to estimate to what extent the census block-level output could be used as an indicator of the level of damage to roadways in the area, we mapped roadway damages in comparison to Hazus damage estimates (see Figure 5). In this, Hazus seems to have a good correlation in the level of total economic loss estimated with the severity of damages to roadways. However, not all roadway segments in affected census blocks required repairs. A further analysis on condition and type of roadway surface, base, etc. as well as proximity to waterways, culverts and low-lying areas could be performed on a localized level to identify high risk segments.

Additionally, we found areas of the region where Hazus either over estimated or underestimated the inundation area. This can be attributed to the resolution of the DEM used for the modeling effort as well as the date of the DEM. In our study, we used multiple DEMs with varying resolution and age in an attempt to gain the most accurate results after realizing that a large area was considered inundated by Hazus which was actually not inundated during the 2010 flood due to construction of a levee in 2004 that was not captured in all the DEMs available to us at the time (Figure 6).

Table 2: Hazus Model Approximations for Damages in Nashville

	Level 2 Analysis (USACE HEC-RAS)	Level 1 Analysis (1000-yr event)
Building loss ($ billion)	2.7	2.24
Business interruption ($ million)	14	14
Transportation system (bridges only) ($ billion)	5.1	5
Utilities ($ billion)	1.4	1.4
Agriculture (million)	20.1	20
TOTAL ($ billion)	9.2	8.64

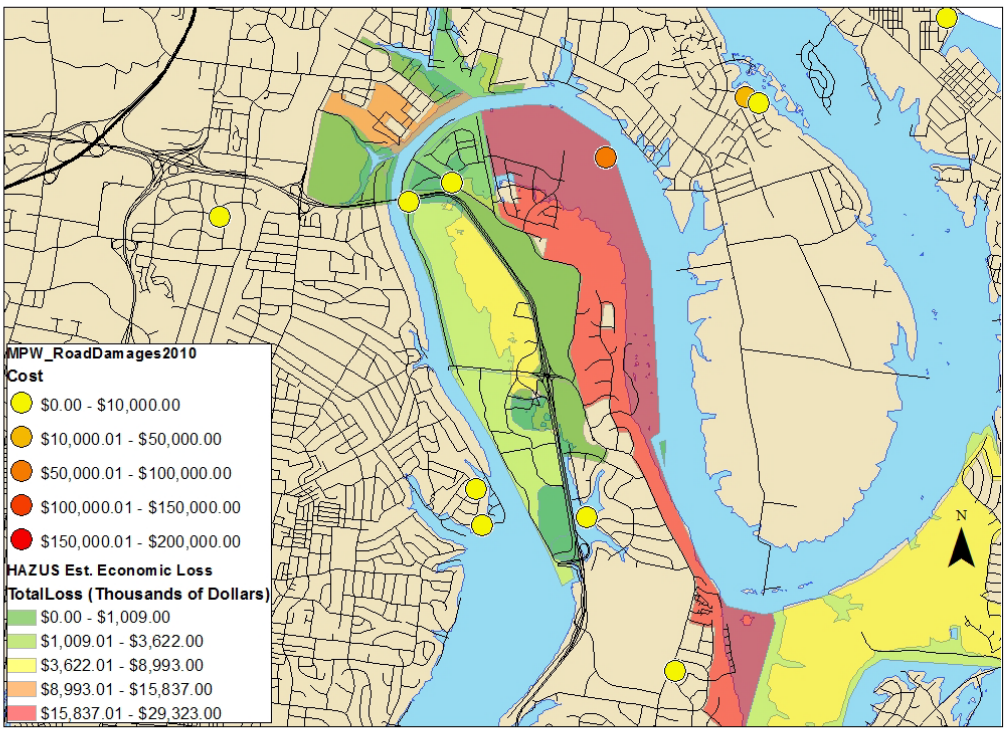


Figure 6: Hazus model output compared to roadway damage repair costs for Nashville area

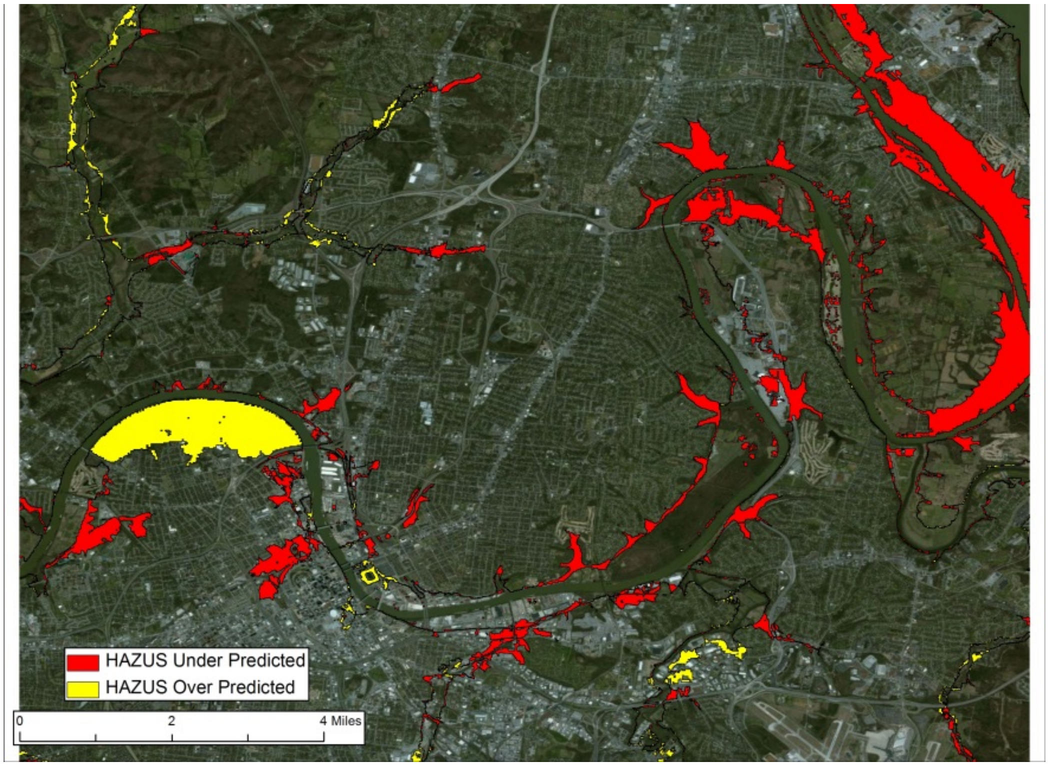


Figure 7: Areas where Hazus 1000-yr flood model over or under estimated the actual inundation from the May 2010 flood event in Nashville

The results of the household survey provided great insight into Hazus's value as a tool to approximate damages (especially indirect damages) for a community despite its lack of consideration for transportation system impacts. For the households surveyed (25% response rate), we found the following:

- 26% had no damages
- 23% had minimal damage
- 18% had moderate damage
- 25% had severe damages
- Only 19% had flood insurance
- 48% had to relocate for at least a short period of time
- 6.5% suffered some type of injury from the flood and spent an average of $280 on medical expenses
- Another 7% had chronic health problems resulting from the flood
- Average household repair and recovery costs (insurance, FEMA, SBA loans, etc.)= $23,800
- Average relocation costs = $1,101
- Average time for recovery = 63 days
- Average equivalent cost for volunteer labor contributions = $19,302

Hazus estimates for the 1000-yr event used to represent the 2010 flood for all of the zones targeted for the survey resulted in the following:

- 7% will require sheltering
- 1.5% will have minimal damage
- 25% will have moderate damage
- 73% will have severe damage
- Average repair/replacement costs = $37K

Therefore, it is apparent that Hazus far underestimated the impacts to the community specifically in terms of indirect costs, but Hazus overestimated the building repair costs. Note, however, that at the time of analysis, Hazus was using 2000 census data which may have skewed the results. Possible considerations for improving the output from Hazus are to re-run the analysis with 2010 census data (available as of 2015 in the latest version of Hazus), account for the over/under estimation of inundation and census block property estimates and demographics associated with those areas, and develop more robust ways to account for localized damage estimations below the census block level. While Hazus doesn't account for damages to transportation infrastructure beyond bridges that may be inundated and the extent to which they are usable, there appears to be potential to use Hazus output as a proxy for level of damage to roadway segments, but more work in this area is needed.

Part 2 – Use of Regionally Downscaled Climate Models to Screen for "At Risk" Transportation Infrastructure

As mentioned earlier, ArcGIS Desktop was utilized to identify "hot spots" for future heavy precipitation under 6 combinations for RGMs and GCMs for 2041-2055 and 2056-2070. The "high" volume highways identified from FAF07 data were superimposed on these as shown in Figure ___.

As one can see, few highway corridors emerge as exceeding the threshold and many are clustered. Using visual examination, it appears that the area around Little Rock, Arkansas, emerges as a critical location under both criteria. A close-up of this area is provided in Figure ___. Not only does this area have high traffic in terms of highways, but it also has a major rail yard (Figure ___).

Following identification of this area as a "hot spot" for both future precipitation and also freight traffic, one can then utilize Hazus to model potential future heavy precipitation events using a 500-yr or 1000-yr return period. The results of a 1000-yr event for this area are presented in Figure ___. A further drill down into the urban area reveals several areas of concern where elevations and current condition of infrastructure assets may be warranted as well as further Hazus or other damage estimation analysis to identify potential risks and options for adaptation to resist or respond to future flooding events.

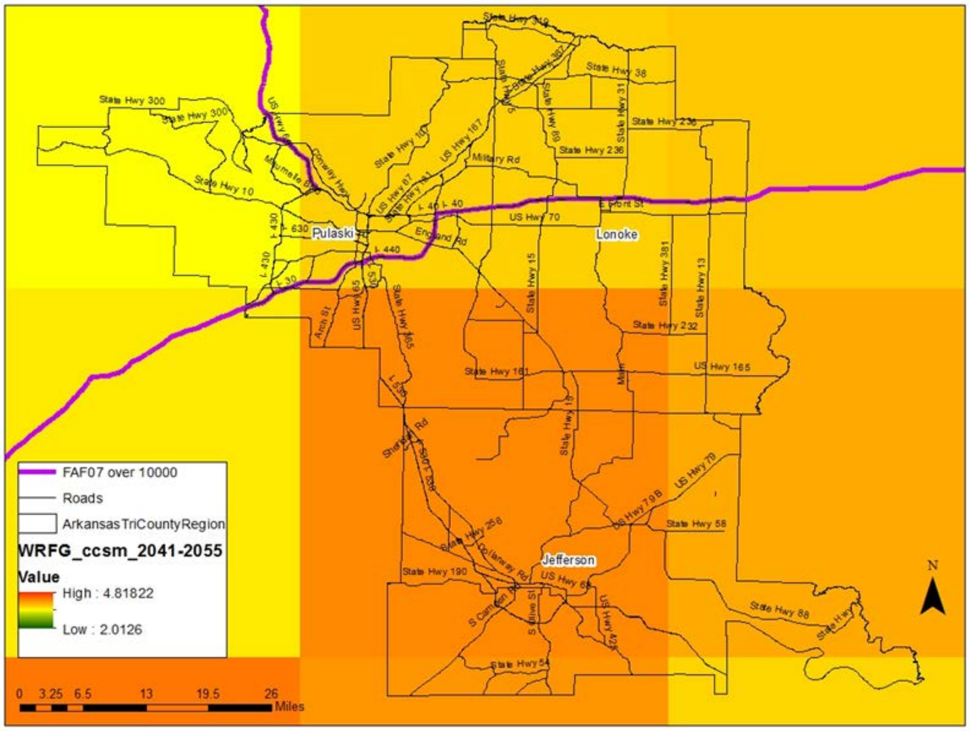


Figure 8: Little Rock, Arkansas area as "hot spot" for both freight transport and future precipitation

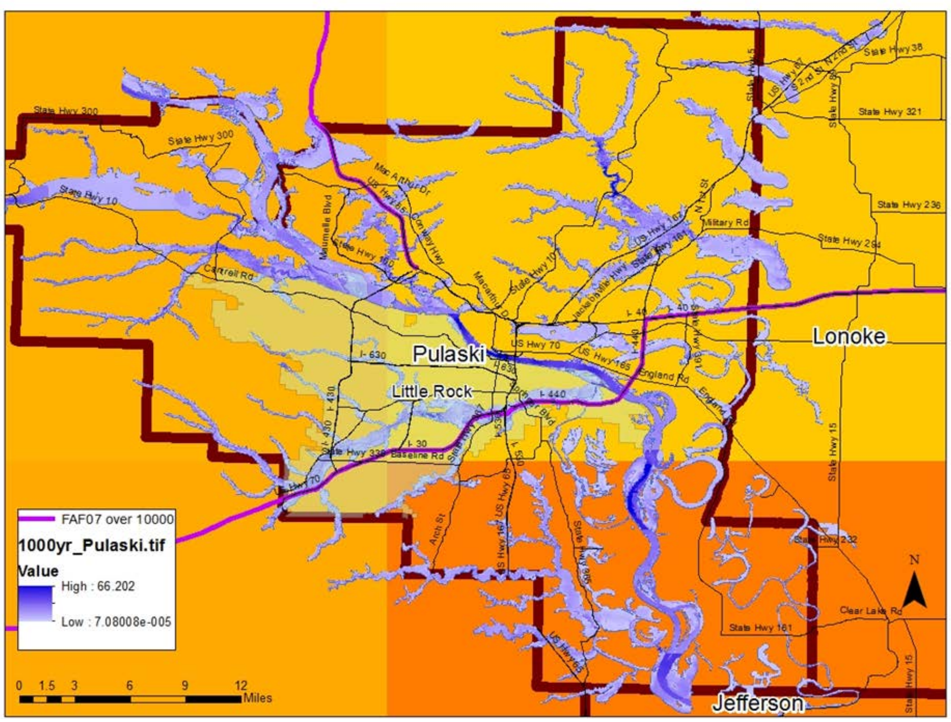


Figure 9: Hazus 1000-yr event inundation for area around Little Rock, Arkansas

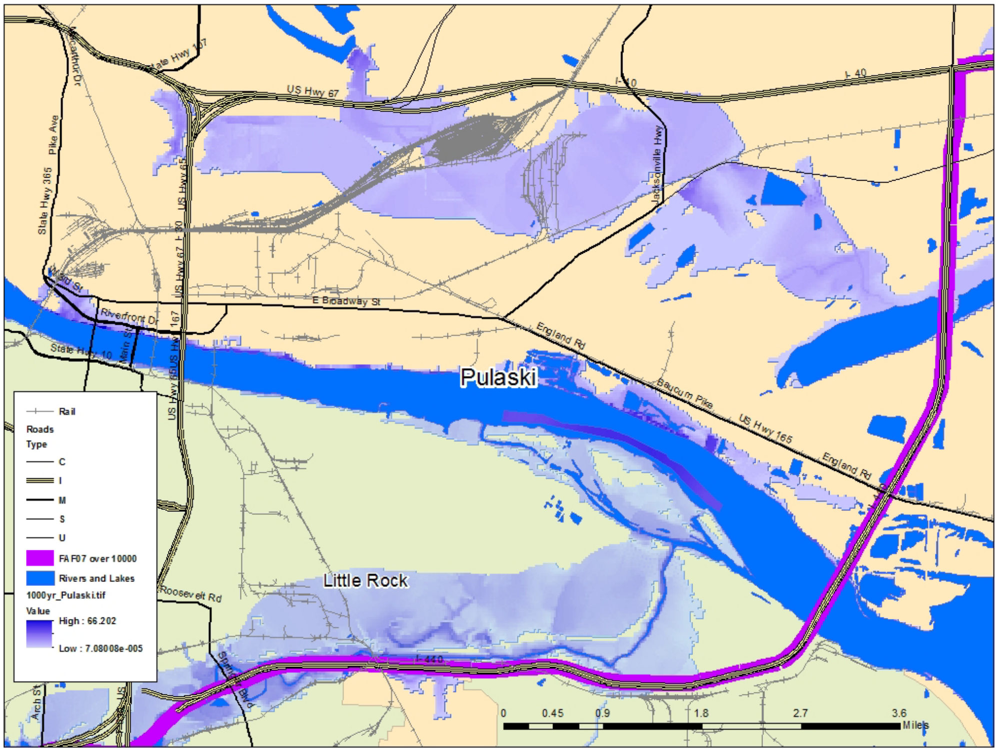


Figure 10: Hazus 1000-yr event inundation for Little Rock, Arkansas with focus on key transportation assets including rail

Conclusions

In this research, we present a local level evaluation of FEMA's Hazus flood model as a tool to estimate damages to a community and also potentially serve as a proxy for the level of impacts to roadway infrastructure during an extreme flood event using the May 2010 flood in the Nashville, TN, area as a test case. Hazus was found to underestimate many of the damages experienced by the Nashville community when compared to local data including household surveys. Hazus can, however, be used for localized screening and further evaluation of roadways and infrastructure assets that may be at risk fr future flooding using modeled 1000-yr events and local information on the condition, elevation, and proximity of assets to waterbodies/inundation areas. Furthermore, we can utilize publicly available regionally downscaled models to perform screening-level analysis of areas of concern under future heavy precipitation frequency. This screening-level analysis can be used to prioritize areas for further analysis using tools such as Hazus to further refine and prioritize which assets or areas may be most at risk and warrant more in-depth study for potential impacts and also adaptation strategies that could be leveraged.

Additional research work in this area as well as publications that provide more detail on the methodology and results are in process.

Appendix A

Household Survey for Nashville

Flood Survey

This survey is about the effects of the May 2010 flood and the costs associated with recovery. Researchers at Vanderbilt University are studying the flood to learn how it affected people and communities. Your answers will help us better understand the costs of flooding. The study is focused on better planning to reduce the impacts of flooding. Please answer the following questions as well as you can. We understand that you may not remember precise numbers—in those cases, please estimate to the best of your ability. All your answers will be kept confidential. If you do not want to answer a specific question, please just mark 'refuse' or leave it blank.

PLEASE RETURN THIS SURVEY BY MARCH 22, 2013, TO RECEIVE YOUR GIFT CARD.

Name (for gift card processing only): ______________________________

---

1) What is your current address: ____

   Did you live here during the May 2010 flood? □ Yes □ No

   If no, what was your address then? ____

2) How badly was your home damaged after the flood? Choose the category that best describes the damage:
   □ No damage
   □ Minimal damage (water in the basement, slightly leaky roof or door, outdoor damage)
   □ Moderate damage (water in main living area)
   □ Severe damage (many feet of water in living area)

3) Did you have flood insurance on May 1, 2010? □ Yes □ No

4) How much did you spend on repairs or replacements?
   Estimated total: $_____________________________

5) Did you have to leave your home to live elsewhere during or following the flood?
   □ Yes □ No -> If no, continue to question 6.
   How long were you away from your residence? ______________
   How much did it cost you to stay elsewhere? _______________

6) How did you pay for repairs and other flood-related expenses? Estimate the amount per category:
   $_________ Retirement or other personal savings
   $_________ Flood insurance or other form of insurance
   $_________ FEMA assistance
   $_________ Gifts or donations from friends, family, work, church, or other groups
   $_________ Loan, mortgage, line of credit, or other type of debt
   $_________ SBA loans
   $_________ We Are Home / other nonprofit grants or loans
   $_________ Other (please specify)

7) How many hours or days (in total) were spent on recovering and rebuilding from the flood?
   ____________ □ Hours □ Days
   How much time was spent on recovering and rebuilding from the flood by each of the following? Estimate the amount per category.
   _____ (□ Hours □ Days) You and/or household family members
   _____ (□ Hours □ Days) Non-household family members or friends
   _____ (□ Hours □ Days) Other volunteers
   _____ (□ Hours □ Days) Hired contractors/workers

8) Were the volunteers from any religious group or other organization (Red Cross, Hands on Nashville, etc.)?
□ Yes □ No -> If no, skip to question 9.

If yes, which group(s) did you receive assistance from and please indicate how much time was spent by each? (You may use the back of this sheet to indicate additional information.)

____

9) After repairs were completed to your home (if any), do you think your residence increased, decreased, or remained at the same value because of the flood? Circle one choice.

Decreased by more than 25%	Decreased 10% to 25%	Decreased by up to 10%	Stayed about the same	Increased by up to 10%	Increased 10% to 25%	Increased by more than 25%

Have you tried to sell your home after the flood? □ Yes □ No -> If No, skip to 10.
Did someone purchase it? □ Yes □ No

- ➔ If no, why not?_______________________________________
- ➔ If yes, was it part of the buyout program? □ Yes □ No -> If No, skip to 10.
- ➔ Do you feel you were given fair compensation for your home? □ Yes □ No

10) Were you or anyone in your household injured as a result of the flood? □ Yes □ No
If no, skip to question 11.

Please indicate the extent of injuries per person (Circle the appropriate response):

	Minor Injuries Not Requiring Medical Treatment	Injuries Requiring Minor Medical Treatment On Site	Injuries Requiring Emergency Room or Hospital Visit	Injuries Requiring Surgery or Extended Hospital Stay
Person 1	1	2	3	4
Person 2	1	2	3	4
Person 3	1	2	3	4
Person 4	1	2	3	4
Person 5	1	2	3	4

You may use the back of this sheet to indicate additional persons with injuries.

11) Have you or anyone in your household experienced other, possibly chronic health problems that you attribute to the flood (e.g., asthma, TB, etc.)? □ Yes □ No

If yes, please indicate the number of individuals in your household that experienced chronic health problems for each of the time durations below.

______ Less than 6 months
______ Between 6 months and 1 year
______ Between 1 year and 2 years
______ Still experiencing chronic health problems today

12) How much money have you and other members of your household spent on medical visits and medications to treat any of these problems? $________________

13) Did you reduce or stop involvement in non-work related activities (social, church, sports, etc.)?
□ Yes □ No If yes, what? _____________________________________

14) In the weeks and months after May 2010, to what degree did people in your household experience anxiety or stress as a result of the flood?

	None	Minor (able to perform most activities normally, but with less ease or satisfaction)	Moderate (able to perform most activities, but with difficulty or little to no satisfaction)	Severe (debilitating and inability to perform daily activities normally)
You, personally				
Other adults in your household				
Your children				

15) To what degree does flood-related anxiety or stress still affect you or people in your household?

	None	Minor (able to perform most activities normally, but with less ease or satisfaction)	Moderate (able to perform most activities, but with difficulty or little to no satisfaction)	Severe (debilitating and inability to perform daily activities normally)
You, personally				
Other adults in your household				
Your children				

16) To what degree was your ability to drive, walk, bike, or otherwise get where you needed to go affected by the flood because of damage to roads, bridges, or other infrastructure? Make an X in the appropriate column for each statement.

	Amount of Impact			**How Long Did the Impact Last?**				
	No Impact	Some	A lot	One day	2 to 6 days	1 to 2 weeks	2 weeks to a month	More than a month
Commuting to work or school								
Appointments (medical, etc.)								
Recreation/community activities (shopping, sports, etc.)								
Other:								

17) How do you normally travel to/from these places? Make an X in the appropriate column for each.

	Mode of Transportation				
	Personal vehicle	Bicycle or walking	Public transit (MTA or otherwise)	Friend or family member	Privately owned paid transportation (cab, etc.)
Commuting to work or school					
Appointments (medical, etc.)					
Recreation/community activities (shopping, sports, etc.)					
Other:					

18) To what degree do you agree or disagree with the following statements? Make an X in the appropriate column for each statement.

	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
My financial situation was negatively affected by the flood					
My neighborhood has fully recovered from the flood					
The flood has strengthened the ties I have with the people in my neighborhood					

19) General questions:

a) Did you rent or own your home in May 2010? □ Rent □ Own

b) Were you employed on May 1, 2010? □ Yes □ No

c) Did you lose your job or business as a result of the flood? □ Yes □ No

d) Which of the following racial categories best describes you?

□ African-American / Black □ Asian, Pacific Islander □ Hispanic / Latino

□ Native American □ White / Caucasian □ Mixed race

□ Other: ______________________________

e) In what year were you born? ________________

f) What was your marital status on May 1, 2010?

□ Single, never married □ Married □Divorced/Separated □Widowed

g) Did you have children or other dependents living at home on May 1, 2010?

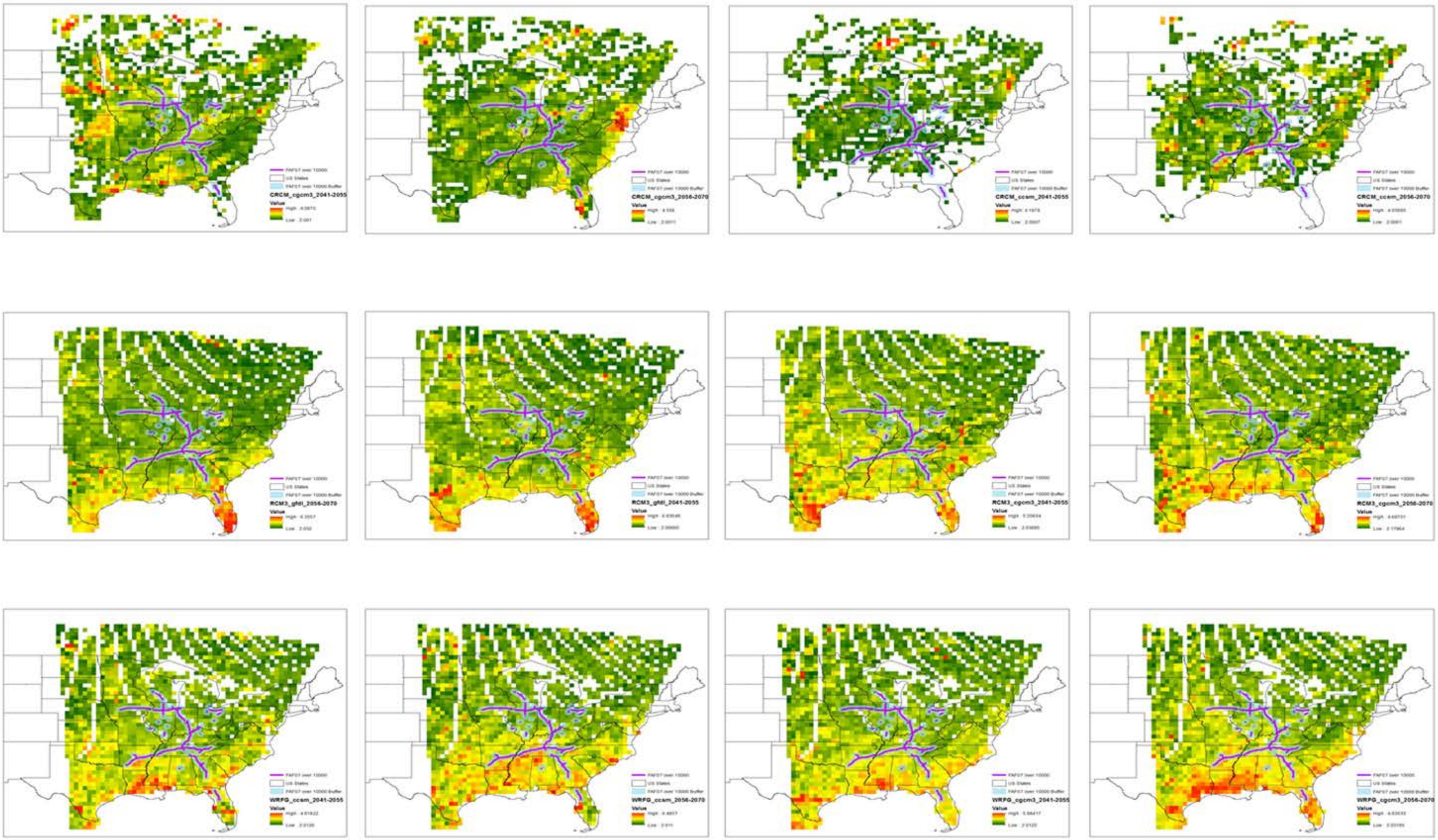
□ Yes □ No

ANY ADDITIONAL COMMENTS:

Appendix B

NARCCAP Model Pairs for Freight System "Hot Spot" Analysis
(Frequency of Daily Average Precipitation Exceeding 2")

Frequency of Daily Average Precipitation over 2”



CFIRE

University of Wisconsin-Madison
Department of Civil and Environmental Engineering
2205 Engineering Hall
1415 Engineering Drive
Madison, WI 53706
Phone: 608-263-9490
Fax: 608-262-519
cfire.wistrans.org